Climate change: Alexandria – Egypt

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General information

Geographically, Alexandria is located approximately at 30°50' to 31°40' north and 29°40' to 32°35' east. The city has a waterfront that extends for 60 km, from Abu-Qir Bay in the east to Sidi Krier in the west and includes a number of beaches and harbours. It extends about 20 miles (32 km) along the coast of the Mediterranean Sea in north-central Egypt. The area is characterized by the irregular hills in the southern parts with an elevation from 0 to 40 meters above mean sea level and slopes towards the Mediterranean Sea in the northward. The entire drainage systems of the Alexandria flow into the Mediterranean Sea. The geology consists of underlying carbonate, sandstone, grits and shales with ground water table lies below 15.0 meters (in most of the area) to 80 meters, and prevalence of artesian well. It is one of the oldest cities on the Mediterranean coast, and is an important tourist, industrial and economic centre. About 40% of all Egyptian industry is located within the governorate of Alexandria. A main source of energy in the city is fossil fuels (Oil and natural gas use in Egypt 92%).

Climatically, Alexandria is a semi-desert, characterized by hot dry summers, moderate winters and very little rainfall. It has only two seasons: a mild winter from November to April and a hot summer from May to October. The difference between the seasons is variations in daytime temperature and changes in prevailing wind. Average annual temperature ranges between minimum of 14˚C in winter and maximum of 30˚C in summer. The average annual temperature increases moving southward from the Delta to the Sudanese border, where temperature variation are similar to those of the open deserts. Alexandria is a one of the wettest area of Egypt, which has an average annual precipitation of about 200 millimetres, which is more compared to the nation's annual average precipitation rate of 80 millimetres. Most of rain falls along the coastal area and it decreases suddenly moving southwards. The humidity in the Alexandria is very high; however sea breeze keeps the moisture down to comfortable level.

A hot spring wind that blows across the country, known as sirocco *(khamsin* for Egyptian) is an important climatic phenomena in Egypt. The wind forms in small but vigorous low pressure area and sweep across the northern coast of Africa. Higher velocity of wind (up to 140km/hr) accompanied by sand and dust from the deserts can increase the air temperature suddenly about 20˚C within two hours. It appears usually in April and occasionally in March and May.

A main source of water in the Egypt is the Nile River, which provides 95% of the water resources. Egypt and the Nile are synonymous and inseparable words, so is Alexandria too. It is flowing north from Sudan enters Egypt directly into Lake Nasser, the reservoir behind the high Aswan dam. The Nile flood, predominantly from the Ethiopian highlands of the Blue Nile, accounts for over 75% of the annual flow and arrives in the three month period from August to October, whereas Lake Victoria Basin adds only roughly 25% (EEAA, 1999). The storage reservoir provides firm annual yields of 55 billion cubic meters (BCM) (75% of its capacity) and is released over the year as needed for agriculture, domestic use, navigation, and energy. Currently, agriculture accounts for 89% of the water use; domestic uses 7%; and industrial and other economic activities account for the 4% (Strzepek & Yates, 2000). The dominant feature of the northern coastal zone is the low lying delta of the River Nile, with its large cities, industry, flourishing agriculture and tourism. The delta and the narrow valley of the Nile comprise 5.5% of the area of Egypt, but have over 95% of its people and its agriculture.

The aim of this note is to introduce about the present and future climatic situations in Alexandria city and water availability in the future. The proceeding sections will briefly explain on the climate change prediction, impacts on urban water systems and adaptation measures to cope with the impacts.

Climate change prediction

IPCC fourth assessment report (IPCC, 2007a) on regional climate projections predicts, warming is very likely to be larger than the global annual mean warming throughout the African continent and in all seasons. The drier subtropical regions are warming more than the moister tropics. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached.

However, it is unclear how rainfall in many regions of Africa will evolve. This is because of the lack of accurate baseline data on current climate (needed to feed into models of future climate) as well as poor representation of two potentially important drivers of African climate variability, namely the El Niño/Southern Oscillation and land cover change in the global climate models (GCMs) (Hulme *et al.*, 2001).

According to IPCC third assessment report (IPCC, 2001), surface warming in the African continent was reported of approximately 0.7°C during the 20th century. Observational records showed that this warming occurred at the rate of about 0.05°C per decade with a slightly larger warming in the June-November seasons than in December-May (Hulme *et al.*, 2001). Based on the IPCC fourth assessment report (IPCC, 2007), temperature increase in Alexandria, per decades since 1979 to 2005, is in the range of 0.05 to 0.15 °C. However, the report is not predicting the change in the precipitation in the same period due to insufficient data to produce reliable trends. IPCC fourth assessment report (IPCC, 2007a) predicts the regional climate variation for North Africa in 2080 to 2099 based on climate change results of 1980 to 1999 for A1B emission scenario, as given in Table 1. Projection shows, rise of mean temperature by 2.8˚C, decrease of precipitation by 6%, and likely few wet seasons and more dry seasons.

Table 1. Climatic projection in North Africa in 2080 to 2099 (Source: (IPCC, 2007a)

Region	Season	Temperature Response (˚C)			Precipitation Response (%)			Extreme Seasons (%)		
		Min	**Average**	**Max**	**Min**	**Average**	**Max**	**Warm**	**Wet**	**Dry**
18N, 20 E to 30N, 65E	DJF	2.4	3.2	5	-47	-18	31	97		12
	MAM	2.3	3.6	5.2	-42	-18	13	100	2	21
	JJA	2.6	4.1	5.8	-53	-4	74	100		
	SOA	2.8	3.7	5.4	-52	6	64	100		
	Annual	2.8	3.6	5.4	-44	-6	57	100		

DJF= December, January, February; MAM= March, April, May; JJA= Jun, July, August; SOA= September, October, November

These projections are based on the average results of 21 different General Climatic models (GCM) for A1B scenario. IPCC third assessment report (TAR) prepared a total 40 emission scenarios. The scenarios were based on the emission driving forces of demographic, economic and technological evolution that produce greenhouse gas (mainly carbon dioxide) and Sulphur emissions. Out of these, IPCC third assessment report of working group-I (2001) (Box 9.1, pp 532), explains about the four scenario 'storylines':A1, A2, B1 and B2.

The A1B scenario is a member of A1 scenario. The A1 storyline and scenario family describe a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

The frequency (%) of extremely warm, wet and dry seasons, averaged over the models, is also presented. The results are shown only when 14 out of the 21 models agree as to the sign of the change in frequency of extremes. The frequency of extreme warmth is 100%, implying that all seasons in 2080 to 2099 are warmer than the warmest season in 1980 to 1999, according to every model in this ensemble.

There are limited studies done to predict the impacts of climate change in basin and city level with a sufficient accuracy. However, impacts of climate change in the country level of Egypt are available in literature. Changes in area averaged temperature and precipitation over Egypt were assessed using a dozen of the recent General circulation models (GCMs) and a new version of a coupled gas-cycle/climate model (MAGICC) with spatial climate change scenario generator (SCENGEN) (OECD, 2004). The results of the MAGICC/SCENGEN analysis are shown in Table 2.

Table 2. GCM estimates of temperature and precipitation change for Egypt (Source: (OECD, 2004)

Year	Temperature change (˚C)			Precipitation change (%)		
	Mean (Standard deviation)			Mean (Standard deviation)		
	Annual	December, January, February	Jun, July, August	Annual	December, January, February	Jun, July, August
2030	1.0 (0.15)	0.8 (0.21)	1.1 (0.18)	-5.2	-8.9	10.7(26.35)
2050	1.4 (0.22)	1.2 (0.30)	1.7 (0.26)	-7.6	-12.8	15.4938.07)
2100	2.4 (0.38)	2.1 (0.52)	2.9 (0.45)	-13.2	-22.3	26.9 (66.28)

All the climate models estimate a steady increase in temperatures for Egypt, with little inter-model Variance. Somewhat more warming is estimated for summer than for winter. With regard to precipitation, models tend to estimate the annual precipitation to fall: net decrease of annual precipitation in winter season is approximately equal to the net increase in summer. The analysis also shows that although both the equatorial lake area and the Blue Nile area are sensitive to changes in the climate, the inflow in Lake Nasser will be mainly controlled by climate changes in the Ethiopian highlands. This because any change in the runoff in the equatorial lake area will be completely dampened by the marshes in southern Sudan. Rainfall on the upper White Nile catchments, the upper Blue Nile catchments, and the Middle Nile basin (which includes the confluence of the two major Nile tributaries), are all showing a decline in total rainfall.

However, whole Egypt relies primarily on the Nile River. Precipitation changes in the water sources of the Nile will affect to water resources in Egypt. Based on the projection of best results of the 17 climate model studied in the source waters of the Nile, in the Ethiopian highlands and equatorial lakes region, is given in Table 3 (OECD, 2004).

Table 3. GCM estimates of temperature and precipitation changes around sources of the Nile (Source: (OECD, 2004)

Year	Temperature change (˚C)			Precipitation change (%)		
	Mean (Standard deviation)			Mean (Standard deviation)		
	Annual	DJF	JJA	Annual	DJF	JJA
2030	1.0 (0.19)	1.0 (0.22)	1.0 (0.23)	1.5 (2.37)	16.6 (18.75)	-0.5 (9.47)
2050	1.4 (0.27)	1.5 (0.32)	1.5 (0.33)	2.1 (3.43)	24.0 (27.09)	-0.7 (13.69)
2100	2.5 (0.47)	2.5 (0.56)	2.6 (0.57)	3.7 (5.97)	41.7 (47.17)	-1.2 (23.83)

From the projection, temperature changes are expected to be similar for both the sources except variation in precipitation. In general, the models on average show an increase in precipitation, however inter-model variation is so high that it is uncertain to predict whether annual average precipitation will increase or decrease. On average, the models projects increase in precipitation in the winter months, whereas slightly decrease in precipitation in the summer months (OECD, 2004).

Sea level rise is another main issue for the Alexandria. IPPC third assessment report (IPCC, 2001) projects average sea level rise by 15cm to 95cm by the year 2100 around Africa. However, it is still a subject of detailed study to predict sea level rise in each coastal area. Frihy (2003) points the three reason of sea level rise in Mediterranean region, which are due to climatic change, local tectonics reason for subsidence/emergence, and seasonal oceanographic and meteorological process. These three causes of sea level rise are valid for the Alexandria. Average rate of subsidence was found to 1mm to 5 mm per year, whereas yearly mean sea level rise is 1.60 mm per year. Consequently, total expected sea level rise is 7.50 mm per year. Therefore, local tectonic reason is important for sea level rise in the Alexandria (Frihy, 2003).

Impacts on urban water systems

IPCC projects (IPCC, 2007b) by 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change in Africa. If coupled with increased population and demand, this will adversely affect livelihoods and exacerbate water-related problems. Urban water systems, based on the rainfall and run-off fed stream flow, and for the city situated in coastal zone will be more vulnerable in the future.

In the Egypt, more than 95% of the water budget is generated outside its territory. Impact of climate change in the Egypt and Alexandria will be governed by the Nile basin sources rather than city level change. Muller (2007) emphasise that small changes in temperature and rainfall will usually be responsible for the amplified changes in water resources systems. For example, with relatively a small changes in rainfall (10–20%) leading to a large changes (up to 75%) in perennial stream flow. However, it is difficult to predict the impact of climate change on the Nile Basin due to prevailing uncertainties. Such as, uncertainties due to variation of the general cycle of the wind, El-Nino and ENSO phenomena as well as uncertainties due to increased frequencies of droughts and their intensities over the last two centuries. As a result, prediction of impact of climate change in the Nile basin is being more complex.

Since Alexandria is situated in the coastal zone of the Egypt. The impacts of climate change can be observed in the water resources; agriculture and food security; human health; ecosystems and biodiversity; costal zones etc. However, impact of climate change in upstream of the Nile River and rising of sea level will be more challenging for the Alexandria in the coming future. Elaborated assessment of climate change impacts in urban water systems is given below.

1) Both water supply and demand are expected to be affected by climate change. Impacts on the supply side are likely to arise from possible changes of precipitation patterns over the Ethiopian hills and equatorial lakes such as Lake Victoria. The impacts were largely dependent on the wide range of inter-model differences in future climate, particularly associated with the direction and magnitude of rainfall change. A Lake Victoria water balance model similar to one first developed by the UK Institute of Hydrology was driven with three climate change scenarios from three GCMs and produced changes in Lake Victoria outflows ranging from -9.2% to +11.8%. Sensitivity analysis showed that a 10% increase in Lake Victoria rainfall caused a 31% increase in runoff and a 4% increase in evaporation caused an 11% decrease in runoff. By combining changes in Lake Victoria outflows with changes in runoff in the other Nile sub-basins, a range of –9% to +12% change in mean annual Nile flows is expected by 2025 (Conway & Hulme, 1996). There are disparities between models on rainfall predictions over both the Blue Nile and White Nile (Hulme *et al.*, 2001). However, temperature rise will lead to greater loss through evaporation placing additional stress on water resources regardless of changes in rainfall. Recent climate scenarios showed decrease in Nile flows from 0 to 40 % approximately (Strzepek *et al.*, 2001).

2) The impacts of sea level rise can be multiple: flood risks on settlement areas; incidence of storms, salt water intrusion; loss of wet lands; loss of recreational beach facilities and negative impact on tourism; loss of coastal infrastructure such as ports, waste water treatment plant; reduced productivity of coastal fisheries; coral reefs bleaching, etc. All the human settlements surrounding the coastal lagoons will potentially come under increased threats of flooding and inundation.

3) Annual and seasonal variation can be produced by a variety of local oceanographic and climatic process, including change in temperature, variation in the strength of coastal currents, atmospheric pressures, and winds blowing. In Alexandria, spring tides raise water level above of 60 cm normal mean sea level. Occasionally, winter storm waves of 1.5 – 3 m height can be observed.

4) For Alexandria, a scenario involving a sea level rise between 0.5 m and 1.0 m over the next century is assumed and if no action is taken, an area of about 30% of the city will be lost due to inundation.

5) It is expected that rate of ground water recharge will be reduced in the future. Salinisation of the coastal aquifers is a function of the reduction of groundwater recharge and result in a reduction of fresh groundwater resources. As a result shallow hand pumps will be affected due to the reduced recharge and lowered groundwater level. Obviously, people using shallow hand pumps will be more vulnerable from climate change.

6) Both long term climate change and shorter term increase in climate variability have an impact on efficacy water supply and sanitation systems. If water supplies become more water stressed, this could reduce the water available for drinking water and hygiene. It could also lower the efficiency of local sewer systems, leading to higher concentration of bacteria and micro organism in raw water supplies. Similarly, increased rate of urban drainage flooding can contaminate the drinking water and groundwater as well as wet lands. The condition of receiving water should be evaluated for the city of the future.

7) There can be many incidence of climate-sensitive disease. For example, i) Rift valley fever, which afflicts people and livestock, is closely related to heavy rainfall events, which is predicted to increase with climate change; ii) Breeding of malaria carriers due to increased flooding; iii) Increase in disease carrying mosquitoes as a result of change in temperature and precipitation. The existing condition of Alexandria should be evaluated from these perspectives to control the disease.

Adaptation measures

It is well known that climate change is already happening, and will strengthen even if global greenhouse gas emissions are curtailed significantly in the short to medium term. This fact combined with Africa's vulnerability to climate change means that planned adaptation is becoming a must. However, it is realized that adoptive capacity for the future climate change depends on the socio-economic condition and main sources of livelihood of the nations. This is more challenging for the poorest and least developed nations having low adoptive capacity due to deteriorating ecological base, widespread poverty, inequitable land distribution and high dependence on the natural resources base (Hulme *et al*., 2001).

For the Alexandria city, sea level rise will be more problem compared to drinking water availability in the future. A few adaptive measures against climate change could be listed as below.

1) Whole Egypt is served by the Nile River, which is a trans-boundary type. The water availability in the future will be decided not only by the basin hydrology and physical changes but also by the other political decisions of other riparian countries. There is a need for dialogue and cooperation among the Nile Basin states to address both technical issues such as sharing of data, as well as more political and sensitive ones such as water allocation.

2) Increased future water demand and possible droughts could be coped with the application of technical strategies to optimize water resources followed by the incentives for a water conservation culture. Such as water demand management, leakage rate reduction, water pricing, water reuse and recycling, water desalination, rain water harvesting, groundwater recharging, reduced imperviousness in the city area, storage reservoir, changing cropping patterns, increasing irrigation efficiency etc.

3) IPCC third assessment report (IPCC, 2001) mentions the three response strategies to rising sea level and its physical impacts: retreat, adapt, or defend. However, the capacity of individual states to undertake such strategies may be limited. Alexandria is most vulnerable from the sea level rise; any one measure can be adopted in response to sea level rise.

4) A state of preparedness to give adequate warning of imminent danger and deliver relief against extreme events related to the climate is a major adoptive measure. Facilities to timely inform about floods and storm can protect more people form extreme events. This is very important for the coastal city like Alexandria.

5) Enacting of programs for upgrading water quality and sanitation to minimize pollution of surface and ground water with a high priority to recycling of industrial and sewage waste.

6) Application of modern techniques for vulnerability assessments of coastal zones, such as remote sensing and GIS.

7) Planning and development of the settlements and infrastructure systems evaluating the impacts of long term and short sea level rise to protect extreme climatic affects like storm, flooding and inundation.

8) Other adaptation measures, such as better link between climate research and policy making, mainstreaming climate change in development plans, and programmes, education and awareness creation in governments, institutions and individuals etc.

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